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THE USE OF THE TRAIL MAKING TEST

WITH BRAIN-DAMAGED AND NORMAL CHILDREN

BY

EUGENE GERALD BRAILSFORD

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E. G. B.

ABSTRACT

In this study, an attempt was made to establish a differential diagnosis of normal children and brain-damaged children of average intelligence, using the Trail Making Test for Organic Brain Damage.

An experimental group was selected which consisted of thirty children who had been diagnosed as brain damaged, by the Provincial Guidance Clinic in Edmonton.

It was hypothesized that there would be a significant difference between the performances of the experimental group and the performance of a control group of normal children, matched for age, sex and intelligence with the experimental group. The hypothesized differences were :

1. That the experimental group would require significantly more time to complete Parts A and B of the Trail Making Test.

2. That Part B will be superior to Part A in this respect.

3. That longer times will be taken to complete the second half of Parts A and B, in differentiating between experimental and control groups more significantly.

4. That the experimental group will make more errors on the Trail Making Test than the control group.

The first hypothesis was supported in part, with Part B differentiating significantly between the experimental

and control groups, and Part A showing strong trends in the desired direction. Part B was found to be superior to Part A in differentiating between the two groups at a high level of significance.

The second hypothesis that Part B would be superior to Part A in differentiating between the groups was supported with a high level of statistical significance.

The third hypothesis was contraindicated. The first half of Parts A and B differentiated significantly between the groups, whereas the second half of each part did not. Furthermore, the percentage of correct classifications obtained on the second half of Part A was not above chance.

The fourth hypothesis was supported in part. The experimental group made significantly more errors than the control group, on Part B of the Trail Making Test. The number of errors made on Part A did not differentiate significantly between the groups.

It was concluded that Part B of the Trail Making Test differentiated significantly between normal children and brain-damaged children in terms of the number of errors made and the time required to complete it.

Theoretical explanations were given for the performance of the experimental group on the Trail Making Test, and suggestions were made for its improvement.

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CHAPTER I

INTRODUCTION

It has only been within the last twenty-five or thirty or so years that a concerted effort has been made to develop psychological tests to indicate the effects of brain damage. Much of the research in this area has been involved in discovering the psychological impairment in adults who have become brain damaged. A proportionately lesser amount of research has been directed toward the brain-damaged child and, as a result, there have been some unwarranted extrapolations made from the psychopathology of brain-damaged adults to that of brain-damaged children. Strauss[37] has pointed out that while the adult has lost or had impaired, the abilities and skills that he once possessed, the brain-damaged child has been thwarted on his way to achieving these abilities. Bender[6] has stressed that children and adults have been shown to react in different ways to similar brain lesions.

Most of those studies which have dealt with the psychopathology of the brain-damaged child have dealt with comparisons between exogenous and endogenous mentally deficient children.[40] Little attention has been paid to Lewis's[24] so-called "other child", the brain-damaged child of average

intelligence who shows few overt symptoms of his injury, yet becomes emotionally disturbed when placed under pressure by those, who, ignorant of his difficulties, expect him to perform and behave at the level of the normal child. In writing about the "other child", Lewis has noted that because of the subtlety of this child's deviations from the normal, his cause has been largely neglected. Medicine and related disciplines have long recognized the problems of education and adjustment of the brain-damaged child who is mentally defective or crippled. However, the child in whom the results of brain damage appear in intellectual and behavioral peculiarities has received less understanding, has often been mistakenly diagnosed in terms of emotional maladjustment or lack of academic ability.

In order that the "other child" be recognized, so that suitable adjustmental and educational environments can be provided for him, enabling him to realize his full potential, techniques used in the diagnosis of brain damage must be more sensitive.

Statement of the Problem

It is the purpose of this study to examine some of the thinking and behavioral difficulties which have been advanced by Strauss,[37] et al as being characteristic of the brain-damaged child of average intelligence. In the present study, it

was felt that the tool most adequate for use in the attempt is the Trail Making Test for organic brain damage, which will be employed. Elaboration of this statement, and the hypotheses which follow it, will be presented following a survey of the literature.

Definition of Terms

Brain-damaged Child. For the purposes of this study, the brain-damaged child is defined as a child who, before, during or after birth, has received an injury to, or has suffered an infection of, the brain.

Perception. For the purposes of this study, perception is defined in accordance with the theory advanced by Strauss, et al [37] as:

> "that activity of mind intermediate between sensation and thought which gives a particular meaning and significance to a sensation, and therefore acts as a preliminary to thinking. The means whereby an individual organizes the stimuli which are continually impinging upon him."

Concept Formation. This term has been interpreted to be defined as: The classification of several precepts according to a common factor which then is a general label which defines that class of percepts. It is, then, the process of abstraction.

CHAPTER II

SURVEY OF THE LITERATURE

This chapter will be a survey of the literature pertinent to the symptomatology of the brain-damaged child, and the methods which are presently being used in diagnosing its presence. An attempt will be made to indicate the shortcomings inherent in these diagnostic methods.

BEHAVIOR DISORDERS IN THE BRAIN-DAMAGED CHILD

A survey of the literature pertaining to disorders in behavior associated with brain damage in children, reveals consistent agreement among the authors regarding the general behavioral traits which are concomitant with cerebral insult. The adjectives applied to such behavior vary with the author's description, but there is a pervasive underlying similarity in these descriptions.

Generally speaking, the brain-damaged child, compared with other children of similar age and level of development, appears to be erratic and emotionally over-active. Such terms as "overactivity", "hypermotility" and "driveness" have been applied to this type of behavior. He has poor powers of concentration. This has been pointed up in the use of terms such as "distractibility", "restlessness", and "short attention span". He is given to sudden rages (irritability, emotional lability),

stubborness (perseveration), and is conspicuously impulsive in manner.[3, 4, 6, 8, 11, 32]

In addition, some authors emphasize the asocial nature of the brain-damaged child due to his lack of inhibition. His history is said to be one of constant complaint regarding his behavior. This Kanner refers to as the "complaint effect".[21] Strauss[37] has written of his "social unacceptability", while others have associated him with such acts as truancy and delinquency.[4]

The rationale underlying the causation of such behavior is still in the theoretic stage. It has been approached from several standpoints. From knowledge provided by the electro-encephlagram, Jasper believes that behavior disorders may be a function of underlying electrical activity. Encephalographic patterns are known to change from moment to moment, particularly in children suffering from convulsive disorders. It is suggested here that the variability of behavior may actually reflect variation in the synchrony of central nervous system elements.[20]

Primary organic and secondary functional reactive postulates have been advanced also, to explain the behavior of the brain-damaged child. Strauss believes it can be explained physiologically in terms of damage to the cerebral cortex :

> All of our emotions, gestures and expressive movements are regulated to a great extent by the diencephalon (old brain). In the course of human development, the cortex develops a softening and inhibiting power which controls excessive emotional reactions and hyperactivity. If this cortical modulation is disrupted by damage to the cortex, the diencephalon acts unchecked, resulting in emotional and psychomotor disinhibition. This is seen in the decreased emotional tolerance apparent in interpersonal relationships.[36]

However, Bender emphasizes the possibility of subsequent difficulties in adjusting to the environment as a basis for the behavior of the brain-damaged child:

> The brain-damaged child is particularly prone to personality, behavior and emotional disorders because of obvious difficulties in social adjustment, and in satisfying their needs , and because of inferiority feelings. Thus, their life situation is often severe enough to account for behavior disorder on a reactive basis alone.[6]

Presumably, then, the brain-damaged child, if provided with a secure and understanding environment, may not display the type of behavior which is consistent with the diagnostic impression of brain damage. A further complicating factor experienced in attempting to make a differential diagnosis is the fact that many of the forms of behavior listed above can be the sole result of functional difficulties, apart from any consideration of being sequalae to brain damage. Lastly, aspects of child development add to the difficulty which becomes apparent when the attempt is made to associate a particular form of behavior syndrome with brain damage, for with the rapid development pace of childhood, it is often difficult to establish what constitutes deviant behavior. As Strauss points out :

> Childhood is the period in which the greatest changes in mental development occur in the shortest time. Particular behavior manifestations can be normal or pathological, depending on their chronological and development stages. For example, playful activity in an eight or nine year old is considered appropriate, while it is taken as a sign of immaturity in a twelve year old.[36]

Thus it appears that there exists no conclusive theory which links the behavior pathology of the brain-damaged child to the brain damage per se. Furthermore, the behavior attributed to brain damage is not unique to that diagnostic category but must be explained from other frames of reference. It must therefore be concluded that brain damage can not be diagnosed on the basis of behavior disorder alone.

THINKING DISORDERS IN THE BRAIN-DAMAGED CHILD

Further light has been shed on the problem through the attempt to understand the thinking disorders characteristic of brain-damaged children. Because of the paucity of literature in this area, we are heavily dependent upon the writings of Strauss, et al[37] for an explanation of the psychopathology of thinking in brain-damaged children. Using the Gestalt theory of perception as a basis,* Strauss relates much of the brain-damaged child's difficulty to disturbances in perception and concept formation.

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* Gestalt psychology has advanced several ingenious experiments to show that perception is the process of organizing the reception of external stimuli by the integration of parts into a whole which is more than the mere summation of the parts. The power of this organization is claimed to be dependent upon the integrity of the nervous system.

Strauss indicates that while the brain-damaged child's sensory equipment is intact, difficulty is experienced in organizing discrete sensations into percepts, by combining them into wholes or "gestalten".

The process of perception in the normal child is such that the "whole" is recognized at once without the scrutiny of details. The stimuli impinging upon his sensory receptors are organized and integrated simultaneously. On the other hand, the brain-damaged child has marked difficulty in organizing his sensory impressions into wholes. He responds to stimuli successively rather than simultaneously. Thus he does not see the stimulus configuration, but his attention is held by separate details which are foreground, the rest background. In attending successively to details, he has difficulty in holding figure and ground relationships separate, and this difficulty increases as the ground becomes more patterned.

Strauss further points out that perceptual difficulties are experienced on higher levels of cerebration, where concept formation is involved. In concept formation, perceptual organization is elaborated by the addition, also in an organized manner, of elements we retain from similar experiences in the past.

> These experiences must be well organized and integrated. The conceptual items can be abstracted only insofar as the experiences from which they are drawn are sufficiently

> well integrated to permit these elements to be isolated, combined and re-combined, while the essential integrity and totality from which they are drawn, is preserved.[37]

The brain-damaged child has trouble in developing concepts because his experiences are not integrated and he can not manipulate them freely. Because his conceptual organization is not firmly held together, he must not tamper with it or it will fall apart. But the development of concepts requires such tampering. So the original set remains dominant and can not be shifted. Thus the brain-damaged child becomes rigid in the scheme he builds.

The brain-damaged child also encounters difficulties in his language development, according to Strauss. As the child differentiates among his concepts, words become symbolic of the differentiations. Through the use of language, concepts are isolated and abstracted from all other concepts.

The environment is constantly changing, causing changes in meaning, and subtleties in interpretations of circumstances. This requires that the child hold in mind a large number of concepts with sufficient flexibility to permit him to combine and re-combine as the situation demands. However, the brain-damaged child has difficulty in combining elements into concepts in the first place, and once he has done this, he clings to what he has. Therefore, although his vocabulary may be average, he has difficulty in making and holding the common serial organizations of words and thoughts which are relevant to the demands

which particular circumstances make upon him.

Certain of the previously mentioned behavior disorders common to a brain-damaged child have been explained by Strauss in terms of his faulty perception and concept formation.

Distractibility is accounted for by his difficulty in structuring his perceptual and conceptual fields. Attending to the discrete elements in a stimulus situation rather than the situation as a whole, his attention tends to wander from detail to detail, successively, thus giving the appearance of having a very short attention span.

Once the brain-damaged child has succeeded in structuring his field, he clings to this accomplishment, and is unable to re-structure it in accordance with producing a satisfactory response to a changing situation, in a short period of time. Thus he responds to a new situation with a structure which has been successful in a previous stimulus situation. This accounts for his perseverative behavior.

Disinhibition is explained, also in his structuring difficulties. Because of his inability to integrate a stimulus situation, he is unable to grasp all the possibilities inherent in the situation and to select the most appropriate response. Responding only to certain details in the situation and failing to see certain consequences upon which the other details depend, his behavior is often seen as disinhibited.

According to Strauss, impulsivity is another concomitant of his unique way of responding. The normal child confronts a

situation with a co-ordinated pattern of perceptions and an elaborate structure of concepts, so that he does not respond to a single stimulus, but to a number of stimuli. Consequently, the stimulus pattern necessary to release autonomic activity is embedded in a wider totality for the normal child than for the brain-damaged child whose perceptual organization is lacking. The simpler organization of the brain-damaged child's perception results in the tendency toward a more specific response, and a releasing pattern is more likely to stand out and gain strength through not being integrated with a larger pattern of stimulation, and so lead to impulsive and explosive behavior.

METHODS EMPLOYED IN THE DIAGNOSIS OF BRAIN DAMAGE

A diagnosis of brain damage in the clinical setting is usually the result of a holistic approach wherein the psychiatrist, psychologist, and social worker present their findings which are the basis upon which the psychiatrist makes the diagnosis.

A. The Psychiatric Examination

The psychiatric examination for brain damage is primarily impressionistic and secondarily mensurate. It involves the intuitive appraisal of the child's behavior in relation to that behavior which is characteristic of the brain-damaged child. The impression gained from this observation is tested further in a neurological examination.

The above discussion of the behavior of the brain-damaged child suggests that certain behavioral disorders are, in themselves,

inadequate bases upon which to advance a definite diagnosis for brain damage.

The examination conducted by the psychiatrist is usually little more than a cursory neurological one and includes the testing of the reflexes and observations of the gait, muscle tones and movement of the child. Depending upon at what point in the growth cycle the injury occurred, one might expect to find any number of neurological signs at the time the child is examined, or none of the customary neurological signs. Strauss[36] emphasizes that these objective tests for motor control are among the crudest in neurology. He further stresses that developmental neurology has not been firmly established, and that the use of adult norms may be inadequate in children of pre-school age, although subsequent to this age, neurological functions become more and more similar.

However, if the psychiatric examination points to the possibility of brain damage, a complete neurological examination and an electro-encephalogram can be recommended and additional signs of brain damage sought from evidence provided by the social history and the results of psychological tests.

B. The Electro-encephalogram

The electro-encephalogram is usually indicative of brain damage in children. As a diagnostic instrument its use is limited, however, to corroborating positive indications of brain damage which have been indicated by other methods.

This is because it quite often reveals similar pathological findings in children with behavior disorders who, on the basis of history and examination, do not belong in the group of brain-damaged children. Strauss has even found it to show deviations in otherwise perfectly normal children.[36]

C. The Social History

The pre-natal and post-natal history of the brain-damaged child often reveals many details which can be interpreted as potential signs of brain damage.

Pre-natal brain damage results from interference with the process during the intra-uterine period. It is usually manifested in a generalized developmental malformation, and not a specific tissue defect. A history of the mother's suffering from German Measles during the first six to twelve weeks would indicate the potentiality of pre-natal brain damage. Other signs pointing to pre-natal brain damage as a result of developmental disturbances, include premature birth, prolonged pregnancy, and necessity for a caesarian birth.

The possibility of brain damage at the time of birth is indicated by such signs as dry birth, the use of forceps, or precipitate delivery.

The occurrence shortly after birth of infectious diseases (particularly whooping cough, measles, scarlet fever, pneumonia, encephalitis, and meningitis) point to a strong possibility of resulting brain damage. A history of trauma to the head, resulting in concussion and skull fracture, occurring any time in an

individual's life, strongly suggests resultant brain damage.

If the occurrence of any of the above phenomena is noted in the social history of an individual, then strong evidence is at hand to support any evidence contained in the psychiatric and psychological examinations of that individual. However, it is often difficult to get such information from the parents. Minor diseases or accidents are forgotten or considered insignificant by the parents.[9, 37]

D. The Psychological Examination

The psychological examination includes the application and interpretation of many psychological tests, some of which are designed especially to detect brain damage, and others which reveal qualitative indications of brain damage, incidentally.

A survey of the literature reveals several approaches which have been taken toward the testing for organic brain pathology in children and adults. Generally, these approaches fall into the following categories :

(a) The analysis of scatter and qualitative impressions derived from individual intelligence tests.

(b) The measure of simple perceptual functions.

(c) Tests of memory for, and reproduction of, designs.

(d) Tests for the ability to abstract.

(e) Personality tests.

(a) Intelligence Tests:

Predominant among tests for intelligence used for testing organic brain pathology are the Wechsler Scales and the Stanford-Binet test. Rabin, et al[13,28] have concluded

after reviews of the W. B. literature, that research to this time has not established the W. B. as a valid measure of organic defect. A recent review of the research done on the Wechsler Intelligence Scale for Children (W.I.S.C.) and the Wechsler Adult Intelligence Scale, has shown that there is general agreement that performance I.Q.'s are generally lower than verbal I.Q.'s in brain-damaged individuals. However, the new scales appear to have shown little improvement over the W. B. scale, as, "at this time the findings relating to specific indicators are inconsistent and, hence, inconclusive".[14] Similar findings have resulted from research on the Binet, using both adults and children as subjects.[7, 19]

(b) The measurement of simple perceptual functions:

Some success in detecting organic brain defect has been obtained in the measurement of simple perceptual functions. The critical flicker frequency in individuals with brain damage, particularly in the occipital and occipital-parietal areas has been found to be lower than that of normals, but there has been considerable overlap in scores between the two groups.[5, 18, 38] There is conflicting evidence as to the effectiveness of the C.F.F. in determining lesions to other areas of the cortex.

(c) Tests of memory for, and reproduction of designs:

Prominent tests for organic brain pathology using the technique of form reproduction only, include the Bender Gestalt, the House-Tree-Person, and the Goodenough Draw-A-Man Test.

A study using Buck's system of scoring categories on the H. T. P., revealed a significant level of differentiation for only one of six categories, that of line quality.[25] Similarly, research on the Bender Gestalt test, using Pascal and Suttel's objective scoring system,[27] revealed a great overlap in the scores of those with mental disorders and those with organic brain defect. The Goodenough test is said to be a good indicator of organic brain injury, but no objective evidence can be found to support this contention. Whether the drawing of a man is impaired or not seems to depend upon the localization of the brain pathology.[26]

A test of form reproduction from memory was designed by Graham and Kendall and validated by the authors,[16] upon an adult population and standardized for adults and children, and shown to have good reliability.[22] However, the authors emphasize that normal visual-motor ability as measured by their test does not imply the absence of brain damage, and that additional factors such as tremor, perseveration and type of damage must be relied upon to aid in clinical differentiation in some borderline cases.[26]

The well known figure-ground reproduction tests include the Kohs Blocks (which is also an intelligence test) and the Grassi Block Substitution test. The diagnostic validity of the Kohs Blocks is said to rest largely on uncontrolled clinical observation. Its effectiveness in differentiating cases of cerebral disease from emotionally disordered childrnn has been questioned.[33]

The Grassi Block Substitution test for Organic Pathology[17] is a relatively new test which is based on somewhat the same principles as the Kohs Blocks. It has been standardized, and reliability is high. There was little overlap in scores between normal, schizophrenic, and brain injured groups. However, the author does not place too much confidence in his statistics, stating that scores on the test, taken alone, will lead to incorrect conclusions. He also stated that intelligence could influence performance, but this was not elaborated upon.[39]

(d) Tests for the ability to abstract:

One of the most widely known of tests of the ability to abstract, which are helpful in determining organic brain pathology is the Goldstein-Sheerer Test of Concept Formation.[15] This test is widely used as a reputable test for brain damage, but it has not been shown to be valid and provides no quantitative data on subjects used, or percentage of incorrect diagnoses. The effects of age and intelligence also are ignored. The test is also used as a test for schizophrenia.[40]

Halstead[18] has combined aspects contained in most of the above approaches, plus tests of auditory and tactual modalities, into Halstead's Neuropsychological Test Battery. The impairment index which he derived from this battery discriminates at a high level of confidence between normals and patients with lesions of the frontal lobes. It does not, however, discriminate between normals and patients with lesions in

other cortical areas.[40]

(e) Personality Tests :

Piotrowski selected ten signs as indicating differentiation between groups of neurotics and normals, and a group of brain-damaged individuals, on the Rorschach. These signs, however, have been carefully checked, and a great deal of overlap was found in the scores of the groups checked.[31]

The Mosaic Test has been shown to reveal signs of brain damage in children. It has proved especially helpful in ruling out brain damage as a cause of autistic and compulsive behavior when used with the Binet and Rorschach.[26]

Molish has pointed to a recent shift from the concern over psychometric evaluation of the organic processes to the assessment of the personality structure of the individual who is reactive to the effects of brain impairment, using projective techniques. However, his review of the literature concerning this area indicates that there is no characteristic personality reaction to brain damage, but that the brain-damaged person reacts according to his individual personality structure.[26]

In conclusion, the above survey would appear to point to Yates'[40] statement that "It is doubtful whether any aspect of psychological testing has been more inadequately treated than the diagnostic assessment of brain damage."

Tests of intelligence are useful only to those who are able to make qualitative judgments based upon extensive experience. Figure-ground reproduction, personality and memory for designs tests would appear to be unreliable, as they contain qualitative norms, dependent upon scorer agreement. Laboratory measures of perception are restricted to the location of the lesion, and it is unlikely that they could be administered routinely to all clinical patients.

In general, most of the representative tests for brain damage reveal too much overlap of scores obtained from different diagnostic groups for them to be efficient tools for differential diagnosis.

It would appear that the following criteria, lacking in present tests for brain damage, are necessary requisites in any tests for brain damage which will be designed in the future:

1. It must achieve a low level of mis-classification of individuals who belong to other diagnostic categories.

2. It must be easily administered so that the effects of examiner bias will not be an uncontrolled parameter.

3. Its scoring method must be objective.

4. Qualitative appraisal must be only incidental in forming any diagnostic conclusions.

CHAPTER III

THE PRESENT STUDY

This chapter will deal with the reasons for selection of the Trail Making Test as a tool for measuring brain damage in children of average intelligence. Hypotheses regarding the thinking disorders tapped by this test, and the procedure by which they will be investigated will be discussed. A description of the characteristics of the experimental group, and the criteria used in its selection, will be given. The control group used for comparison with the experimental group will be described, and reasons for selecting them examined. The statistical procedure to be employed to the data will be presented.

Selection of the Tool

The Trail Making Test may possibly satisfy the four criteria which were advanced in the last chapter as being necessary bases for tests of organic brain damage. It is an ideomotor test consisting of two parts, A and B. Part A consists of 25 circles distributed over a white sheet of paper and numbered 1 - 25. The subject is required to connect the circles with a pencil line as quickly as possible, beginning with number one and proceeding in numerical sequence. Part B consists of 25 circles numbered 1 - 13, with letters A to L.

The subject is required to connect the circles, alternating between numbers and letters as he proceeds in ascending sequence. The score is obtained as the number of seconds needed to finish each part. The administration of each part of the test is preceded by the administration of a small practice test containing a sample of the test proper (cf. Appendix B for sample forms and instructions).

The Trail Making Test originated as one of the performance subtests of the Army Individual Test.[1] It is a relatively unknown instrument which has been adapted in the last decade by several investigators who have utilized it in making studies concerning its use as a measure of brain damage.

The ability of the Trail Making Test to measure certain functions suggested its use in this area. The basis of its usefulness appeared to reside in its tapping such functions as :

1. the ability to integrate previously learned material into a pattern of response that involved shifts in organization, recall and recognition;
2. the ability to maintain a double relationship;
3. the ability to plan foresightfully.[10]

Armitage[2] was the first to use it for this purpose. He was able to show to a highly significant degree, differences

between brain-damaged individuals and a control group composed of normals and neurotics; the controls making fewer errors and showing a greater ability to recognize and correct them.

Reitan[29] applied the Trail Making Test to a group of brain-damaged and to a group of hospital patients with various physical diseases, who were matched for race, age, sex and education. Highly significant intergroup mean differences were found. His conclusion was that, "This short, inexpensive and easily administered test may be a fairly valid indicator of certain effects of brain damage." A further study undertaken by Reitan using a larger brain-damaged population furnished essentially the same results.[30]

These findings were not corroborated by Brown, et al[10] who administered the Trail Making Test to all patients admitted to a clinical setting. The scores obtained did not show discriminative diagnostic value as scored by the time taken to complete the test, there being little difference between the scores of psychotics and organics.

Only one study[26] has measured the performance of children on the Trail Making Test. It was administered to groups of normal children, cerebral palsied children and children who were psychiatric patients, all matched for age and intelligence. Normals were found to have less variable

performance, and performed significantly better than the other groups. The performance of the psychiatric group tended toward the normals, and away from the cerebral palsied group.[11]

It is probable that this study was vitiated by the use of an experimental group who were spastic, the purpose of the Trail Making Test not being to measure overt motor impairment, but underlying neural processes.

The Trail Making Test appears to be well suited for the testing of certain of the hypotheses advanced by Strauss in his discussion of thinking disorders in brain-damaged children (cf. pp. 7 -11). It involves the organization of stimuli on the perceptual level in a constantly changing figure-ground situation. It also taps the individual's ability to maintain a serial conceptual set and (Test B only) to shift from one conceptual set to another, very quickly.

Hypotheses

The nature of the task requirements of the Trail Making Test suggests that the brain-damaged child will, in his performance on it, behave in accordance with the following hypotheses :

1. That he will experience difficulty in organizing the stimuli provided by the test, into a perceptual and conceptual configuration. This difficulty will be reflected in the longer time required to complete each part of the test, as compared with the time required by a matched control subject.

2. That Part B of the Trail Making Test will be superior to Part A in differentiating between brain-damaged and normal children because of the additional requirement therein, that the subject must constantly shift from one conceptual framework (numbers) to another (letters).

3. That the times taken to complete the second halves of Part A and Part B will differentiate more significantly between brain-damaged children and normal matched children for two reasons :

   (a) In the second half of each test the span of attention or conceptual set will have been in operation over a longer period of time, and the possibility of loss of set because of distraction from the task, will increase.

   (b) In the second half of the test, the pencil work up to that point will have resulted in creating a more complex and (for the brain-damaged child) confusing figure-ground relationship.

4. That the brain-damaged child will make more errors in the Trail Making Test than the normal child, because of his perseverative mode of response even when the response is inadequate. In Part B this tendency will be further increased by his rigidity which will result in an inability to shift from a numerical to alphabetical sequence consistently.

<u>Selection of the Experimental Group</u>

From the files of the Provincial Guidance Clinic, Edmonton, thirty children were selected for the experimental group, all of whom met the following criteria :

1. Age : six to sixteen

2. Intelligence : Average or above average (as measured by the Binet intelligence scale or the Wechsler Intelligence Scale for Children.

3. No visual impairment or lack of gross motor co-ordination.

4. A positive diagnosis of brain damage under the following classifications :

    (a) Generalized brain damage

    (b) Aphasia

    (c) Auditory agnosia

    (d) Chronic brain syndrome: Post encephaletic

    (e) Epilepsy: sub-clinical, petit mal, grand mal and ideopathic.

The diagnosis of brain damage was made according to four methods:

1. Social history of brain trauma or brain disease

2. Psychological tests

3. Psychiatric behaviour appraisal and neurological examination

4. Electro-encephalogram

The survey of the literature has indicated that these methods, taken by themselves, are not conclusive in the diagnosing of brain damage. However, it was assumed that a positive finding by three of the above was sufficient to warrant a positive diagnosis of brain damage, and the subjects were selected accordingly.

The average age of the experimental group was 9.90 years; the average level of intelligence of the experimental group was an I.Q. score of 104.

Diagnostic Classifications of Experimental Group	Number of Subjects
Generalized Brain Damage	12
Aphasia	2
Auditory Agnosia	1
Chronic Brain Syndrome (Post Encephalitis)	1
Epilepsy: Grand Mal, Petit Mal, Sub-clinical and Idopathic	14
	30

Table I - Diagnostic Classifications of Experimental Group

Selection of the Control Group

In an effort to hold educational, socio-economic, and cultural factors constant, each member of the experimental group was matched with a normal child in the same classroom. A child was classified as being normal on the strength of his teacher's opinion that he was not emotionally disturbed, and by the absence of a Guidance Clinic record. Each member of the control group was matched for age, and for intelligence with a member of the experimental group on the basis of a similar score on the group intelligence test administered by the schools which they both attended. Such tests as the Detroit Beginners, Detroit Advanced, California Mental Maturity, and Otis Self Administering, intelligence scales were used in the various schools from which the subjects came. The average age of the control group was 9.98; the average level of intelligence of the control group was an I.Q. score of 103. Individual statistics concerning these children are included in Appendix B.

Ages of Matched Pairs	Number of Pairs
Age 6 to 8	7
Age 8 to 10	11
Age 10 to 12	5
Age 12 to 14	5
Age 14 to 16	2
	30

Table II - Ages of Matched Pairs of Subjects

Administration and Scoring of Test

The Trail Making Test was administered to both brain-damaged and normal children in random order according to the procedure outlined in the Manual prepared by R. M. Reitan.* The test was administered in the school setting, usually in the guidance room or the medical room of the school that the testee was attending. The experimental group came from twenty-four different schools, fifteen public schools and nine separate schools.

Two stop watches were used to record times. One stop watch recorded the time taken to perform one-half of each subtest, while the other recorded the time taken to perform each entire subtest. A note was made of the number of errors made on each subtest. An error was defined as the

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* This Manual is available only in mimeograph form.

joining of one symbol to another symbol which was not in sequence. In the event that the subject was unable to complete a subtest, he was arbitrarily assigned a time of ten minutes on Part B, five minutes on Part A. The number of errors assigned to the individual in this case was ten.

Statistical Procedure

Because of the inability to meet the assumptions of homogeniety of variance and normality of distribution which underly parametric tests for significance, a non-parametric test, the Wilcoxon Matched-Pairs Signed-Ranks test was employed. *

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* The formula used for arriving at the critical ratio was the one given by Seigle.[33]

$$Z = \frac{T - u_t}{\sigma_T} = \frac{T - \frac{N(N+1)}{4}}{\sqrt{\frac{N(N+1)\ (2N+1)}{24}}}$$

Results were considered significant at the .01 level.

CHAPTER IV

RESULTS

The discussion of results will be divided into four parts. The first part will evaluate the validity of the first two hypotheses, that the brain-damaged child will require more time to complete each part of the Trail Making Test than a normal child, and that Part B of the Trail Making Test will be superior to Part A in differentiating between brain-damaged and normal children.

The second part will deal accordingly with hypothesis number three, that the times taken to complete the second half of each test will differentiate more significantly between brain-damaged and normal children than the times taken to complete the whole of each test.

The third part of the discussion will involve an appraisal of hypothesis number four, which stated that more errors will be made by the brain-damaged child than the normal child, on the Trail Making Test.

Part four will contain a brief discussion of the qualitative aspects of behaviour in the brain-damaged child, as observed during his performance on the Trail Making Test.

Part I

		A		B
Mean (Time in Seconds) . . .	N	59.81	N	203.26
	BD	76.07	BD	302,16
Z		1.97*		3.097 **
% Correct Classification . .		63.34		75.00

* Significant at the .025 level
** Significant at the .001 level

Table III - Scores Obtained on Part A and Part B of the Trail Making Test

Examination of the data supplied in Table III tends to support the first hypothesis in part. The data presented in Table I was obtained by comparing the differences in time taken to complete Parts A and B of the test by normal and brain-damaged children. The brain-damaged children required, on the average, approximately sixteen seconds more to complete Part A, and one minute, thirty-nine seconds more to complete Part B. The difference obtained in the Part B scores, is statistically significant at the .001 level. The level of significance obtained on Part A falls short of the requirements laid down as indicating satisfactory proof of the hypothesis. However, a strong trend towards supporting the first hypothesis is indicated.

	B-A (BD) - B-A (N) Mean Difference (Time in Seconds)	Z
BD	269.7	3.21*
N	173.0	

* Significant at the .001 level.

Table IV - Comparisons Between Part B-A (BD) Scores and Part B-A (N) Scores

Table IV lends strong evidence in support of the second hypothesis, that Part B of the Trail Making Test is superior to Part A in differentiating between normal children and brain-damaged children. The results in Table II were obtained by calculating the differences in scores between Part A and Part B for brain-damaged children and for normal children. There appears to be a significantly greater difference between scores on Part A versus scores on Part B for the brain-damaged children than for the normal children.

Part II		A(First Half)		B(First Half)
Mean (Time in Seconds) . . .	N	29.63	N	82.26
	BD	41.03	BD	123.60
Z		2.81*		2.91**
% Correct Classification		66.66		67.86

* Significant at the .0025 level.
** Significant at the .0018 level.

Table V - Scores Obtained on the First Halves of Parts A and B of the Trail Making Test

	A(Second Half)		B(Second Half)	
Mean(Time in Seconds). . .	N	30.23	N	117-8
	BD	25.83	BD	167-43
Z		1.002**		1.935*
% Correct Classification . .		50		63.07

* Significant at the .16 level
** Significant at the .03 level

Table VI - Scores Obtained on the Second Halves of Parts A and B of the Trail Making Test

Reference to Tables V and VI reveals evidence which is contraindicative to hypothesis number three. Little difference was shown to exist between the performances of the brain-damaged and normal children on the second half of Parts A and B. The levels of significance in each case were lower than those set down in the hypothesis. Also on Part A, the percentage of correct classifications between individual pairs was not above chance.

On the other hand, the first half of each subtest appears to differentiate very significantly between brain-damaged and normal children. It appears then, that the reverse of the hypothesis is the case.

Part III

	A		B	
Mean (Errors)	N	.33	N	2.10
	BD	.53	BD	3.40
Z		1.008*		2.56**
% of subjects who made one or more errors . .	N	23.33	N	63.3
	BD	33.3	BD	80.00

* Significant at the .19 level
** Significant at the .006 level

Table VII - Errors Made on Part A and Part B of the Trail Making Test

Table VII indicates that the number of performance errors made is of little consequence in differentiating between brain-damaged and normal children on Part A of the Trail Making Test. Few errors were made by either group and the level of significance was low.

However, the number of errors made by the brain-damaged group on Part B was significantly greater than those made by the normal group as was the percentage of subjects in the brain-damaged group who made errors. Characteristic perceptual rigidity was noted in the brain-damaged children responsible for their increase in errors on Part B. Upon being faced with an error they would usually become confused and unable to shift. This would lead to a repetition of the original error until its significance was grasped.

Part IV - Qualitative Aspects of the Brain-Damaged Child's Behaviour on the Trail Making Test

Certain behaviour traits were noted in some of the brain-damaged children while performing the test, which were not seen in the normal children. These traits were not consistently seen in the brain-damaged children but the observation of any of them would lend further corroboration to a positive diagnosis based on a time score alone.

One of the most noticeable aspects of the brain-damaged child's behaviour was seen in his attitude toward the test. On many occasions the test was approached in a carefree, happy-go-lucky way, with much confidence, and little concern. This characterisitc lack of inhibition would appear to have the potential of aiding the child's performance, especially when contrasted with the tenseness and involvement that some of the normal children exhibited. However, the lack of anxiety probably resulted in carelessness and may account in part for the increased number of errors made by the brain-damaged children.

Impulsivity was noted in some of the brain-damaged children. Evidence for this was observed in the child's beginning the test as soon as a pencil was handed to him, without waiting for instructions to begin. Another indication was the child's extending a line from the last symbol joined before he had located the next symbol to be joined.

Number sequence seemed to be fairly well integrated in the brain-damaged children, but not so the alphabet sequence. On more than one instance, a child would proceed from one letter to the next by taking a verbalized "run" at it, hence reciting the alphabet from the first, many times.

Perceptual difficulties were noted in the occasional reversal or inversion. For example, the subject would join 21 to 11 instead of 12; G to L instead of G to 7.

The brain-damaged child's reaction to pressure was perhaps best illustrated in the verbalization of one eight year old, who said "Don't make me go so fast, 'cause that's when I get mixed up."

CHAPTER V

DISCUSSION

The findings of this study agreed only in part with the hypotheses which were advanced. An explanation for these discrepancies must lie in either a weakness in the theory advanced by Strauss regarding the thinking disorders in brain-damaged children or in the inability of the Trail Making Test to tap those thinking disorders postulated by Strauss.

The hypothesis that Part A of the Trail Making Test would differentiate between brain-damaged and normal children on the basis of the time taken to complete it, was not supported at the required level of significance. The main reason for this appears to be that Part A did not sufficiently challenge the basis of conceptual difficulty which Strauss attributes to the brain-damaged child.

The requirement in Part A is that numbers be joined sequentially. The number sequence has been learned by most school-aged children by constant repetition, to the extent that the ability to count has for them, become routine. So in Part A the brain-damaged child is not presented with a novel task which demands "the ability to combine and recombine (a large number of concepts) as the situation demands."[37]

On the other hand, Part B employs two conceptual sequences which must be maintained simultaneously and integrated, one within the other. This task resembles closely the type of situation in which Strauss would expect the brain-damaged child to encounter difficulties. It is not surprising that Part B differentiated between the brain-damaged and normal child at the required level of significance, as hypothesized.

It was hypothesized that the time taken to complete the second halves of Part A and B of the Trail Making Test would differentiate more significantly between the brain-damaged and normal child because the conceptual set would be held over a longer period of time and the perceptual ground would be more complex. This hypothesis was not substantiated.

This suggests that neither the length of time that the set was held, nor the increased complexity of the perceptual ground presented a significantly greater amount of difficulty for the brain-damaged child than for the normal child.

However, contrary to expectations, the time taken to complete the first half of Part A differentiated significantly between the two groups in contrast to the ability of the whole of Part A to do so. (The second half of Part B did not serve to increase the significance of the differentiation of the two groups on the basis of time.)

The explanation for this turn of events would seem to reside in the brain-damaged child's experiencing comparatively more difficulty in confronting a large number of concepts which must be sequentially organized in a setting which involves many choices or possibilities.

The nature of this difficulty may be accounted for in the brain-damaged child's spacial perception, i.e., his inability to perceive positionally as quickly as does the normal child. On this basis, he would experience less difficulty as the number of concepts to be perceived diminished by elimination. This would account for his performance on the second half of Part A not being significantly different from that of the normal child.

Another explanation for the increased difficulty experienced by the brain-damaged child on the first half of Part A may lie in the child's initial confusion at being confronted with an unfamiliar situation. As he became more familiar with the task requirements, his confusion diminished. The fact that the brain-damaged child did not experience significantly more difficulty on the first half of Part B than on Part B complete, lends further strength to this interpretation.

Part B differentiated significantly between the two groups on the basis of the number of errors made as hypothesized. However, Part A did not do so. The explanation here again would appear to be that Part A did not sufficiently challenge the brain-damaged child of average intelligence.

CHAPTER VI

RECOMMENDATIONS

The present study was involved with studying certain of the behaviour characteristics of the brain-damaged child of average intelligence. It also determined to measure the efficiency of the Trail Making Test, in diagnosing brain damage in children whose intelligence was relatively unimpaired. Part A of the Trail Making Test was not found to be efficient in discriminating between brain-damaged children of average intelligence and comparable normal children, either on the basis of number of errors made or time taken to complete it, although strong trends were noted in the direction of the latter. Part B was seen to show promise in each of these respects.

This study was , at best, a pilot project. The groups of subjects were small in number and heterogenous in make-up. However, it did indicate that further use of Part B, employing large numbers of subjects, may result in the compilation of scoring norms which might prove valuable in differentiating between brain-damaged and normal children. The greater divergence of scores between brain-damaged and normal children on Part B

may enable a cut-off score to be established for children of various ages, which would involve fre misclassifications.

In the case of the exogenous feeble-minded child, any increase in the difficulty of the Trail Making Test would probably measure his lack of intelligence rather than his organic involvement. A recent study by Reitan, in which the Wechsler-Bellevue scores and the Trail Making Test scores of brain-damaged adults were compared, revealed a significant relationship between intelligence and Trail Making Test performance.[29]

The present study has shown that in the case of brain-damaged children of average intelligence, the increase in difficulty of Part B over Part A has resulted in increased differential significance. The discriminative power might be further increased by the addition of a further sequence category, such as Roman numerals. Thus the perceptual and conceptual complexity of the task would be further increased. When norms have been obtained for different levels of intelligence, children of various intelligence levels could be tested for brain damage using that part of the Trail Making Test which was appropriate for his level of intelligence: Part A for those below average intelligence, Part B and the above-mentioned addition for children of average or above intelligence.

However, before such an undertaking is attempted, a weakness of the present study must be eliminated. Before it can be concluded that Part B of the Trail Making Test is a valid test for brain damage, the difference in performance between brain-damaged children and neurotic and psychotic children must be investigated. Functional disturbances as well as organic disturbances impair mental functioning. Neurotics complain of poor memory, inability to concentrate and inability to make decisions, among other things. Psychotics show a variety of impaired patterns, faulty judgment and a low level of conceptual thinking, perhaps being the most outstanding. Lack of sufficient number of subjects with clear-cut diagnoses of neurosis or psychosis prevented the study's being carried into this area.

Certain educational prognostic implications emerge from the examination of the behaviour of the brain-damaged child on the Trail Making Test. His trouble here was primarily in his reaction to a large number of stimuli. Once the number of stimuli was reduced, his performance was not significantly different from that of the normal child. This suggests that the brain-damaged child could function quite adequately in the school setting if he were introduced to a limited number of stimuli at a time and given time to integrate or consolidate this before proceeding further.

This would, of course, mean a slower rate of advancement, but would ensure a lessening of frustration and the emotional reactions which accompany it.

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APPENDIX A

INDIVIDUAL CHARACTERISTICS OF THE CONTROL AND EXPERIMENTAL GROUPS

MATCHED PAIRS

	Control Group	Experimental Group
1.	Sex: Male Age: 7 - 6 I.Q.: Detroit Advanced, 124 Normal	Sex: Male Age: 7 - 7 I.Q.: Detroit Advanced, 125 Generalized Brain Damage
2.	Sex: Male Age: 13 - 14 I.Q.: Laycock, 118 Normal	Sex: Male Age: 13 - 6 I.Q.: Detroit Advanced, 125 Epilepsy, Secondary to Brain Damage
3.	Sex: Male Age: 8 - 5 I.Q.: Detroit Beginners, 89 Normal	Sex: Male Age: 8 - 5 I.Q.: Detroit Beginners, 94 Brain Damage, Sub-Clinical Epilepsy
4.	Sex: Female Age: 8 - 10 I.Q.: Calif. Ment. Mat., 104 Normal	Sex: Female Age: 8 - 0 I.Q.: Detroit Beginners, 111 Ideopathic Epilepsy
5.	Sex: Female Age: 7 - 8 I.Q.: Detroit Beginners, 99 Normal	Sex: Female Age: 7 - 8 I.Q.: Detroit Advanced, 102 Auditory Agnosia
6.	Sex: Female Age: 9 - 3 I.Q.: Calif. Ment. Mat., 89 Normal	Sex: Female Age: 9 - 3 I.Q.: Detroit Beginners, 90 Sub-Clinical Epilepsy
7.	Sex: Male Age: 11 - 4 I.Q.: Detroit Beginners, 108 Normal	Sex: Male Age: 10 - 11 I.Q.: W. I. S. C., 109 Aphasia
8.	Sex: Male Age: 11 - 2 I.Q.: Detroit Beginners, 108 Normal	Sex: Male Age: 11 - 10 I.Q.: Detroit Advanced, 105 Sub-Clinical Epilepsy

	Control Group	Experimental Group
9.	Sex: Male Age: 8 - 5 I.Q.: Calif. Ment. Mat., 104 Normal	Sex: Male Age: 8 - 2 I.Q.: W. I. S. C., 105 Sub-Clinical Epilepsy
10.	Sex: Male Age: 8 - 5 I.Q.: Calif. Ment. Mat., 98 Normal	Sex: Male Age: 8 - 3 I.Q.: Calif. Ment. Mat., 94 Sub-Clinical Epilepsy
11.	Sex: Male Age: 8 - 0 I.Q.: Detroit Advanced, 118 Normal	Sex: Male Age: 8 - 3 I.Q.: Detroit Advanced, 117 Epilepsy
12.	Sex: Male Age: 8 - 2 I.Q.: Detroit Beginners, 125 Normal	Sex: Male Age: 7 - 9 I.Q.: Detroit Beginners, 120 Generalized Brain Damage
13.	Sex: Female Age: 13 - 0 I.Q.: Laycock, 104 Normal	Sex: Female Age: 13 - 2 I.Q.: Laycock, 102 Sub-Clinical Epilepsy
14.	Sex: Male Age: 13 - 4 I.Q.: Laycock, 93 Normal	Sex: Male Age: 13 - 0 I.Q.: Laycock, 94 Epilepsy
15.	Sex: Female Age: 6 - 9 I.Q.: Detroit Beginners, 128 Normal	Sex: Female Age: 6 - 2 I.Q.: Detroit Beginners, 121 Chronic Brain Syndrome, Post Encephalitis
16.	Sex: Male Age: 12 - 11 I.Q.: Laycock, 104 Normal	Sex: Male Age: 14 - 1 I.Q.: Laycock, 104 Grand and Petit Mal Epilepsy

	Control Group	Experimental Group
17.	Sex: Male Age: 11 - 5 I. Q.: Laycock, 95 Normal	Sex: Male Age: 11 - 0 I. Q.: W. I. S. C., 89 Generalized Brain Damage
18.	Sex: Male Age: 10 - 5 I. Q.: Laycock, 109 Normal	Sex: Male Age: 10 - 6 I. Q.: Laycock, 109 Generalized Brain Damage
19.	Sex: Female Age: 14 - 9 I. Q.: Laycock, 112 Normal	Sex: Female Age: 14 - 10 I. Q.: Laycock, 110 Sub-Clinical Epilepsy
20.	Sex: Male Age: 10 - 6 I. Q.: Detroit Beginners, 88 Normal	Sex: Male Age: 10 - 8 I. Q.: W. I. S. C., 84 Generalized Brain Damage
21.	Sex: Male Age: 9 - 1 I. Q.: Detroit Beginners, 90 Normal	Sex: Male Age: 9 - 1 I. Q.: Binet, 88 Generalized Brain Damage
22.	Sex: Male Age: 9 - 3 I. Q.: Calif. Ment. Mat., 93 Normal	Sex: Male Age: 8 - 11 I. Q.: W. I. S. C., 87 Aphasia
23.	Sex: Male Age: 13 - 4 I. Q.: Detroit Beginners, 92 Normal	Sex: Male Age: 14 - 8 I. Q.: Detroit Beginners, 91 Sub-Clinical Epilepsy
24.	Sex: Male Age: 6 - 4 I. Q.: Detroit Beginners, 90 Normal	Sex: Male Age: 6 - 8 I. Q.: Detroit Beginners, 90 Epilepsy
25.	Sex: Male Age: 7 - 1 I. Q.: Detroit Beginners, 91 Normal	Sex: Male Age: 6 - 9 I. Q.: Binet, 98 Generalized Brain Damage

	Control Group	Experimental Group
26.	Sex: Female Age: 7 - 8 I. Q.: Detroit Beginners, 95 Normal	Sex: Female Age: 8 - 6 I. Q.: Detroit Beginners, 103 Generalized Brain Damage
27.	Sex: Male Age: 9 - 4 I. Q.: Otis Quick Scoring, 90 Normal	Sex: Male Age: 9 - 7 I. Q.: Detroit Beginners, 89 Generalized Brain Damage
28.	Sex: Male Age: 8 - 2 I. Q.: Otis Quick Scoring, 124 Normal	Sex: Male Age: 8 - 7 I. Q.: Otis Quick Scoring, 123 Mild Brain Damage
29.	Sex: Male Age: 7 - 2 I. Q.: Otis Quick Scoring, 96 Normal	Sex: Male Age: 7 - 1 I. Q.: Binet, 89 Minor Brain Damage
30.	Sex: Male Age: 16 - 4 I. Q.: Terman MacNermar, 124 Normal	Sex: Male Age: 16 - 3 I. Q.: Terman MacNermar, 128 Epilepsy

APPENDIX B

INDIVIDUAL SCORES OBTAINED BY MATCHED PAIRS ON THE TRAIL MAKING TEST

Test A - First Half

Pair	Time in Seconds Brain Damaged	Time in Seconds Normals	Difference in Secon ds	Rank of Difference	Rank With Less Frequent Sign
1	103	27	76	30.0	
2	18	19	- 1	- 2.0	- 2.0
3	43	23	20	21.0	
4	85	29	56	29.0	
5	45	59	- 14	- 15.0	- 15.0
6	80	48	32	23.0	
7	11	29	- 18	- 19.5	- 19.5
8	24	15	9	13.5	
9	18	34	- 16	- 16.5	- 16.5
10	27	25	2	4.5	
11	18	19	- 1	- 2.0	- 2.0
12	30	24	6	10.0	
13	9	14	- 5	- 8.0	
14	17	22	- 5	- 8.0	
15	78	94	- 16	- 16.5	- 16.5
16	14	13	1	2.0	
17	60	19	41	25.5	
18	21	13	8	12.0	
19	10	19	- 9	- 13.5	- 13.5
20	19	22	- 3	- 6.0	- 6.0
21	77	34	43	27.0	
22	41	34	7	11.0	
23	31	14	17	18.0	
24	98	43	55	28.0	
25	42	73	31	22.0	
26	41	23	18	19.5	
27	32	34	- 2	- 4.5	- 4.5
28	59	18	41	25.5	
29	71	35	36	24.0	
30	9	14	- 5	- .8	- 8.0
Totals	1,231	885			95.5

$$Z = \frac{95.5 - \frac{(30)(31)}{4}}{\sqrt{\frac{(30)(31)(61)}{24}}} = \frac{-137}{48.68} = -2.81$$

$$Z \propto \quad = \quad .0025$$

Test A - Second Half

Pair	Time in Seconds Brain Damaged	Time in Seconds Normals	Difference in Seconds	Rank of Difference	Rank With Less Frequent Sign
1	61	31	30	25.0	
2	12	21	- 9	- 12.0	- 12.0
3	54	25	29	24.0	
4	82	31	51	26.0	
5	27	52	- 25	- 21.5	- 21.5
6	55	36	19	18.0	
7	13	28	- 15	- 17.0	- 17.0
8	14	17	- 3	- 3.0	- 3.0
9	30	18	12	16.0	
* 10	27	27	0		
11	26	15	11	14.5	
12	29	25	4	6.0	
13	12	18	- 6	- 8.5	- 8.5
14	15	21	- 6	- 8.5	- 8.5
15	67	134	- 67	- 27.0	- 27.0
16	14	17	- 3	- 3.0	- 3.0
17	29	18	11	14.5	
18	43	18	25	21.5	
19	12	15	- 3	- 3.0	- 3.0
20	26	49	- 23	- 20.0	- 20.0
21	48	27	21	19.0	
22	38	41	- 3	- 3.0	- 3.0
23	125	21	104	28.0	
24	32	42	- 10	- 13.0	
25	41	47	- 6	- 8.5	- 8.5
* 26	27	27	0		
27	33	30	3	3.0	
28	25	19	6	8.5	
29	51	23	28	23.0	
30	7	14	- 7	- 11	- 11.0
Totals	1,075	907			159.0

$$Z = \frac{159 - \frac{(28) \cdot (29)}{4}}{\sqrt{\frac{(28)\ (29)\ (57)}{24}}} = \frac{-44}{43.91} = 1.002$$

$Z \propto \quad = \ .1587$

* In the event of tied scores occurring between individuals in pairs, the pair is dropped from the sample, in calculating Z

Test A - Total

Pair	Time in Seconds Brain Damaged	Time in Seconds Normals	Difference in Seconds	Rank of Difference	Rank With Less Frequent Sign
1	103	58	45	20.5	
2	30	39	- 9	- 7.0	- 7.0
3	137	48	89	28.0	
4	167	61	106	29.0	
5	72	111	39	19.0	
6	135	84	51	23.0	
7	24	57	- 33	- 16.5	- 16.5
8	38	32	6	5.5	
9	48	52	- 4	- 4.0	- 4.0
10	54	52	2	2.0	
11	44	34	10	8.5	
12	59	49	10	8.5	
13	21	32	- 11	- 10.0	- 10.0
14	30	43	- 13	- 13.0	- 13.0
15	145	228	- 83	- 27.0	- 27.0
16	27	30	- 3	- 3.0	- 3.0
17	89	37	52	24.0	
18	64	31	33	16.5	
19	22	34	- 12	- 11.5	- 11.5
20	45	71	- 26	- 15.0	- 15.0
21	125	61	64	25.5	
22	79	73	6	5.5	
23	156	35	121	30.0	
24	130	85	45	20.5	
25	83	120	- 37	- 18.0	- 18.0
26	68	50	18	14.0	
27	65	64	1	1.0	
28	84	37	47	22.0	
29	122	58	64	25.5	
30	16	28	- 12	- 11.5	- 11.5
Totals	2,282	1,794			136.5

$$Z = \frac{136.5 - \frac{(30)(31)}{4}}{\sqrt{\frac{(30)(31)(61)}{24}}} = \frac{-96.0}{48.68} = -1.97$$

$$Z \ \alpha = .0244$$

Part A - Errors

Pair	Errors Normals	Errors Brain Damaged	Difference	Rank of Difference	Rank With Less Frequent Sign
1	2	2			
2					
3		2	2	8	
4					
5					
6		2	2		
7					
8	1		- 1	- 3	3
9					
10					
11					
12					
13					
14					
15	2		- 2	- 8	8
16					
17		1	1	3	
18	1		- 1	- 3	3
19					
20	1				
21					
22	1	1			
23		2	2	8	
24		2	2	8	
25	1	1			
26					
27					
28		1	1	3	
29	1	2	1	3	
30					
Totals	10	16			14

$$z = \frac{14 - \frac{9\ (10)}{4}}{\sqrt{\frac{9\ (10)\ (18 + 19)}{24}}} = \frac{8.5}{8.43} = 1.008$$

$$z\ \alpha = .1836$$

Test B - First Half

Pair	Time in Seconds Brain Damaged	Time in Seconds Normals	Difference in Seconds	Rank of Difference	Rank With Less Frequent Sign
1	300	103	197	25.0	
2	26	53	- 27	- 15.0	- 15.0
3	201	109	92	22.0	
4	175	85	90	21.0	
5	135	105	30	16.0	
6	94	84	10	8.5	
7	78	69	9	7.5	
8	68	85	- 17	- 13.0	- 13.0
9	73	59	14	11.0	
10	94	70	24	14.0	
11	72	56	16	12.0	
12	62	96	- 34	- 17.0	- 17.0
* 13	31	31			
14	54	57	- 3	- 3.0	- 3.0
* 15	300	300			
16	39	51	- 12	- 10.0	- 10.0
17	251	43	208	26.0	
18	73	23	50	20.0	
19	34	32	2	1.0	
20	58	61	- 3	- 3.0	- 3.0
21	282	87	195	24.0	
22	300	83	217	27.0	
23	78	36	42	18.0	
24	300	165	135	23.0	
25	212	216	- 4	- 5.0	- 5.0
26	59	67	- 8	- 6.0	- 6.0
27	300	58	242	28.0	
28	77	34	43	19.0	
29	153	156	- 3	- 3.0	- 3.0
30	29	19	10	8.5	
Totals	3,708	2,468			75.0

$$Z = \frac{75 - \frac{(28)(29)}{4}}{\sqrt{\frac{(28)(29)(57)}{24}}} = \frac{-128}{43.89} = 2.916$$

$$Z \propto = .0018$$

* In the event of tied scores occurring between individuals in pairs, the pair is dropped from the sample, in calculating Z

Test B - Second Half

Pair	Time in Seconds Brain Damaged	Time in Seconds Normals	Difference in Seconds	Rank of Difference	Rank With Less Frequent Sign
1	300	109	191	26.0	
2	25	33	8	4.0	
3	300	122	78	17.0	
4	142	168	- 26	- 10.0	- 10.0
5	176	175	1	1.0	
6	148	141	7	3.0	
7	153	125	28	28.0	
8	245	50	195	27.5	
9	179	41	138	22.0	
10	300	161	139	23.0	
11	68	104	- 36	- 12.0	- 12.0
12	52	119	- 67	- 15.0	- 15.0
13	35	44	- 9	- 5.0	- 5.0
14	51	73	- 22	- 9.0	- 9.0
* 15	300	300			
16	c39	22	- 17	- 7.5	- 7.5
17	169	29	140	24.0	
18	48	86	- 38	- 13.0	- 13.0
19	33	100	- 66	- 14.0	- 14.0
20	231	52	179	25.0	
21	207	308	- 101	- 20.0	- 20.0
22	300	105	195	27.5	
23	185	54	131	21.0	
24	300	209	91	19.0	
25	286	282	4	2.0	
26	126	110	16	6.0	
27	300	90	210	29.0	
28	86	161	- 75	- 16.0	- 16.0
29	208	127	81	18.0	
30	42	23	17	- 7.5	- 7.5
Totals	5,023	3,523			129.0

$$z = \frac{129 - \frac{(29)(30)}{4}}{\sqrt{\frac{(29)(30)(59)}{24}}} = \frac{-89.5}{46.24} = 1.935$$

$z = 1.935. \quad \alpha = .0265$

* In the event of tied scores occurring between individuals in pairs, the pair is dropped from the sample, in calculating z

Test B - Total

Pair	Time in Seconds Brain Damaged	Time in Seconds Normals	Difference in Seconds	Rank of Difference	Rank With Less Frequent Sign
1	600	212	388	27	
2	51	86	- 35	- 11	- 11
3	518	231	287	25	
4	317	253	64	14	
5	311	280	31	9	
6	237	225	12	3	
7	231	194	37	12	
8	313	135	178	24	
9	252	100	152	20	
10	401	231	170	21	
11	150	162	- 12	- 3	- 3
12	114	215	- 101	- 18	- 18
13	66	75	- 9	- 3	- 3
14	105	130	- 25	- 7	- 7
* 15	600	600			
16	78	73	5	2	
17	420	72	348	26	
18	121	109	12	3	
19	67	132	- 65	- 15	- 15
20	289	113	176	23	
21	489	395	94	17	
22	600	188	412	28	
23	263	90	173	22	
24	600	454	146	19	
* 25	498	498			
26	179	177	2	1	
27	600	148	52	13	
28	163	195	- 32	- 10	- 10
29	361	283	78	16	
30	71	42	29	8	
Totals	9,065	6,098			67

$$Z = \frac{67 - \frac{(28)\,(29)}{4}}{\sqrt{\frac{(28)\,(29)\,(57)}{24}}} = \frac{-136}{43.91} = -3.097$$

$Z\ \alpha = .001$

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* In the event of tied scores occurring between individuals in pairs, the pair is dropped from the sample, in calculating Z

Part B - Errors

Pair	Errors Normals	Errors Brain Damaged	Difference	Rank of Difference	Rank With Less Frequent Sign
1	3	10	7	23	
2	1		- 1	- 3	3
3	2	3	1	3	
4		1	1	3	
5		2	2	9	
6	1		- 1	- 3	3
7	1	4	3	14.5	
8	4	7	3	14.5	
9		3	3	14.5	
10	2	6	4	19.5	
11	2		- 2	- 9	9
12	4		4	19.5	
13					
14	1	1			
15	10	10			
16	2		2	9	
17	5	1	- 4	- 19.5	19.5
18	2	2			
19					
20		4	4	19.5	
21	6	10	4	19.5	
22	1	10	9	25	
23		4	4	19.5	
24	2	10	8	24	
25		2	2	9	
26	5	3	- 2	- 9	9
27		3	- 3	- 14.5	14.5
28			2	9	
29	5	3	- 2	- 9	9
30		1	1		
Totals	63	102			67

$$Z = \frac{67 - \frac{(25)(26)}{4}}{\sqrt{\frac{(25)(26)(51)}{24}}} = \frac{-95.5}{37.16} = 2.56$$

$$Z\alpha = .0052$$

Differences in Sub Test Time Scores Between:

Part B - Part A (Brain Damages)
and Part B - Part A (Normals)

Pair	B-A(BD)	B-A(N)	(1)-(2)	Rank of Difference	Rank With Less Frequent Sign
1	531	181	350	28	
2	39	65	- 26	- 9	- 9
3	464	206	258	27	
4	235	222	13	6	
5	284	228	56	14	
6	182	189	- 7	- 4	- 4
7	218	166	52	13	
8	299	118	181	24	
9	222	82	140	21	
10	374	204	170	23	
11	124	147	- 23	- 8	- 8
12	85	190	- 105	- 20	- 20
13	54	57	- 3	- 2	- 2
14	90	109	- 19	- 7	- 7
15	533	466	67	16	
16	64	56	8	5	
17	391	54	237	26	
18	178	91	87	19	
19	55	117	- 62	- 15	- 15
20	273	64	209	25	
21	441	368	73	18	
22	562	147	415	29	
23	138	69	69	17	
24	568	412	156	22	
25	457	451	6	3	
26	152	150	2	1	
27	567	118	449	30	
28	138	176	- 38	- 11	- 11
29	310	260	50	12	
30	64	28	36	10	
Totals	8,092	5,191			76

$$Z = \frac{76 - \frac{(30)\,(31)}{4}}{\sqrt{\frac{(30)\,(31)\,(61+1)}{24}}} = \frac{-156.25}{48.61} = 3.21$$

$$Z \propto = .001$$

APPENDIX C

PROCEDURE FOR ADMINISTERING AND SAMPLE FORMS FOR THE TRAIL MAKING TEST

THE TRAIL MAKING TEST

PART A

Procedure for Administering

When ready to begin the test, place the Part A test sheet, sample side up, flat on the table directly in front of the examinee, and with the bottom of the test sheet approximately six inches from the examinee's edge of the table.

Give the examinee a pencil and say:

Sample

On this page (point) are some numbers. Begin at number 1 (point to 1) and draw a line from 1 to 2, (point to 2), 2 to 3 (point to 3), 3 to 4 (point to 4), and so on, in order, until you reach the end (point to the circle marked "end"). Draw the lines as fast as you can. Ready! Begin!

If the examinee completes the sample item correctly, and in a manner which shows that he knows what to do, say:

Good! Let's try the next one.

Turn the page and give Part A, test.

If the examinee makes a mistake on Sample A, point it out and explain it. The following explan ations of mistakes are authorized :

1. You started with the wrong circle. This is where you start (point to No. 1).

2. You skipped this circle (point to the one omitted). You should go from Number 1 (point) to 2 (point), 2 to 3 (point) and so on, until you reach the circle marked "end" (point).

3. You only went as far as this circle (point). You should have gone to the circle marked "end" (point). After the mistake has been explained, say :

Mark out the wrong part and go on from here (point to the last circle completed correctly in the sequence).

If it is clear that the examinee intended to touch a circle but missed it, do not count it as an omission. Caution him to touch the circles, however.

If the examinee still can not complete Sample A, take his hand and guide his pencil (eraser end down) through the trail. Then say :

Now you try it. Put your pencil, point down. Remember, begin at number 1 (point) and draw a line from 1 to 2 (point to 2), 2 to 3 (point to 3), 3 to 4 (point to 4), and so on, in order until you reach the circle marked "end" (point). Do not skip around but go from one number to the next in the

proper order. If you make a mistake, mark it out. Remember, work as fast as you can. Ready! Remember, work as fast as you can. Ready! Begin!

If the examinee succeeds this time, go on to Part A. If not, repeat the procedure until he does succeed, or it becomes evident that he can not do it.

Turn the page over to Part A, and say :

Part A Test

On this page are numbers from 1 to 25. Do this the same way. Begin at number 1 (point) and draw a line from 1 to 2 (point to 2), 2 to 3 (point to 3), 3 to 4 (point to 4), and so on, in order until you can reach the end (point). If you make a mistake, mark it out. Remember, work as fast as you can. Ready! Begin!

Start timing. If the examinee makes an error, call it to his attention immediately and have him proceed from the point the mistake occurred. Do not stop timing.

If the examinee completes part without error, remove the test sheet. Record the time in seconds. Errors count only in the increased time of performance. Then say :

That's fine. Now we'll try another one.

Proceed immediately to Part B, Sample.

PART B

Procedure for Administering

Place the test sheet for Part B, sample side up, flat on the table in front of the examinee, in the same position as the sheet for Part A was placed. Point with the right hand to the sample and say :

Sample

On this page are some numbers and some letters. Begin at Number 1 (point) and draw a line from 1 to A (point), A to 2 (point to 2), 2 to B (point to B), B to 3 (point to 3), 3 to C (point to C), and so on, in order, until you reach the end. (Point to circle marked "end"). Remember, first you have a number (point to 1), then a letter (point to A), then a number (point to 2), then a letter (point to B, and so on. Draw the lines as fast as you can. Ready! Begin!

If the examinee completes the sample item correctly, say :

Good. Let's try the next one.

Proceed immediately to Part B.

If the examinee makes a mistake on Sample B, point it out and explain it. The following explanations of mistakes are authorized.

1. You started with the wrong circle. This is where you start (point to Number 1).

2. You skipped this circle (point to the one omitted). You should go from 1 (point) to A (point), A to 2 (point to 2), 2 to B (point to B), B to 3 (point to 3), and so on until you reach the circle marked "end" (point).

3. You only went as far as this circle (point). You should have gone to the circle marked "end" (point). After the mistake has been explained, say:

Mark out the wrong part and go on from here (point to the last circle completed correctly in the sequence).

If it is clear that the examinee intended to touch a circle but missed it, do not count it as an omission. Caution him to touch the circles, however.

If the examinee still can not complete Sample B, take his hand and guide the pencil (eraser end down) through the circles. Then say:

Now you try it. Remember, you begin at Number 1 (point) and draw a line from 1 to A (point to A) A to 2 (point to 2), 2 to B (point to B), B to 3 (point to 3), and so on until you reach the circle marked "end" (point). Ready! Begin!

If the examinee succeeds this time, go on to Part B. If not, repeat the procedure until he does succeed, or it

becomes evident that he can not do it.

Turn the page over to Part B, and say :

Part B Test

On this page are both numbers and letters. Do this the same way. Begin at Number 1 (point) and draw a line from 1 to A (point to A), A to 2 (point to 2), 2 to B (point to B), B to 3 (point to 3), 3 to C (point to C), and so on, in order, until you reach the end (point to circle marked "end"). Remember, first you have a number (point to 1), then a letter (point to A), then a number (point to 2), then a letter (point to B), and so on. Do not skip around, but go from one circle to the next in the proper order. If you make a mistake, mark it out. Draw the lines as fast as you can. Ready! Begin!

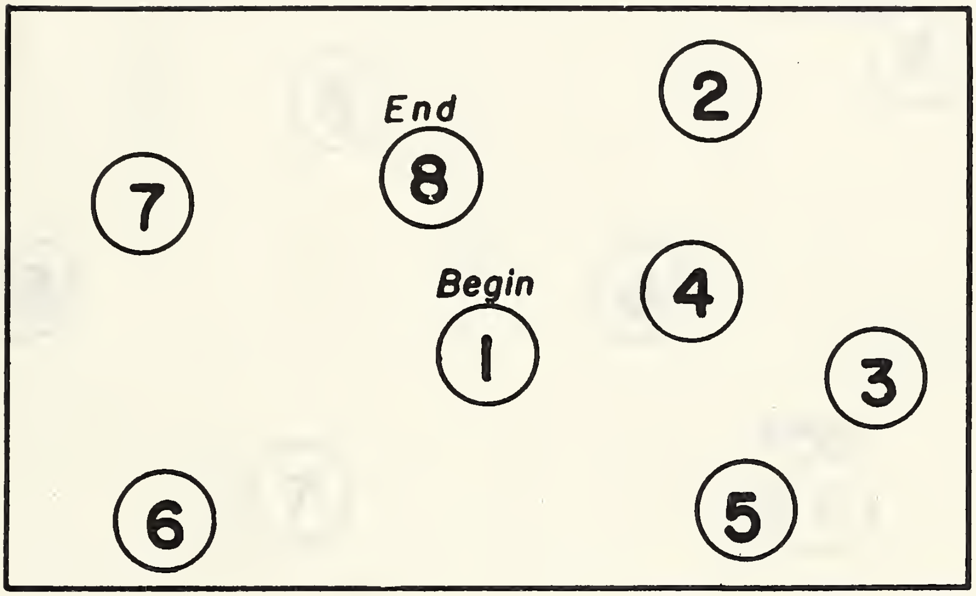
Start timing. If the examinee makes an error, call it to his attention immediately and have him proceed from the point the mistake occurred. Do not stop timing.

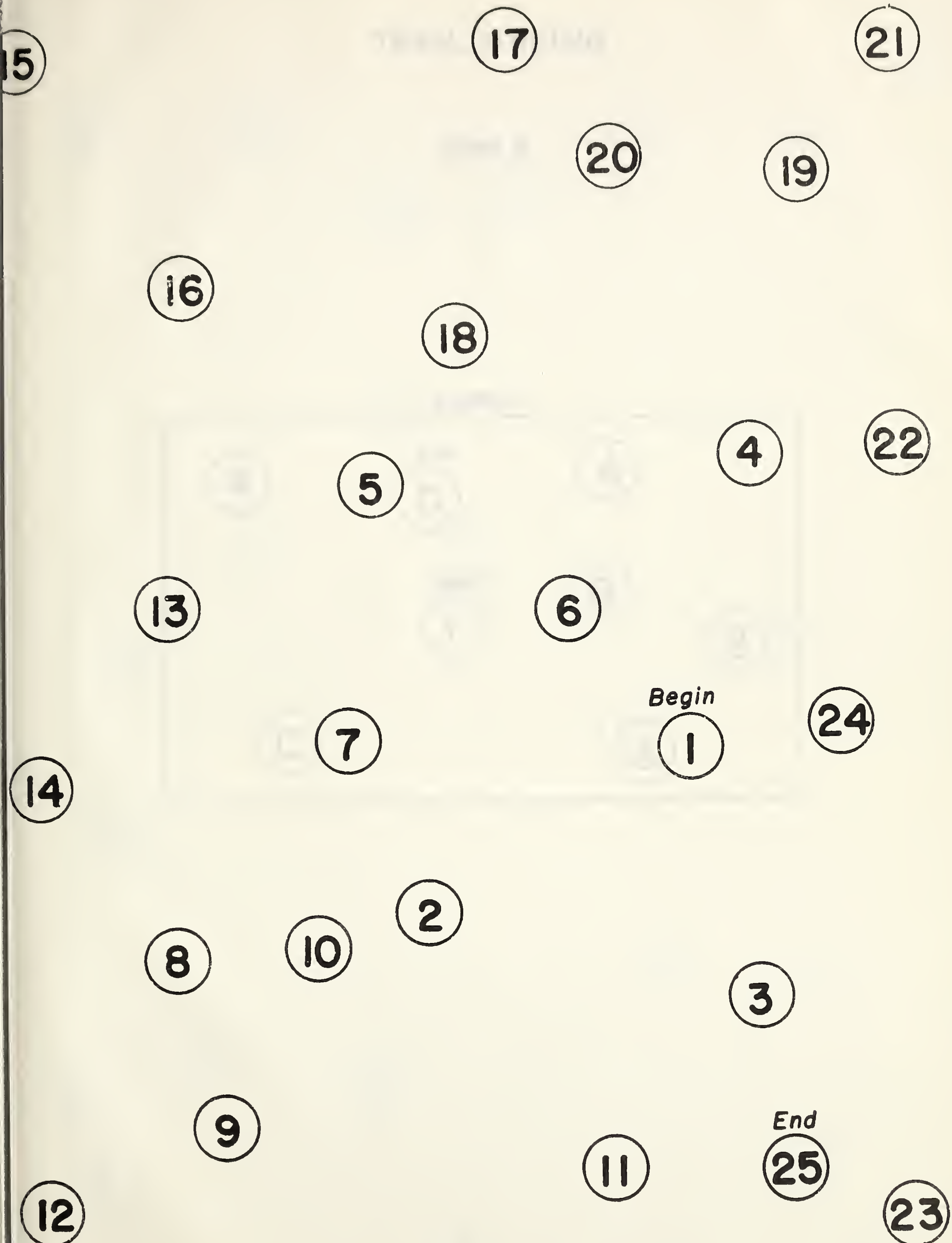
If the examinee completes Part B without error, remove the test sheet. Record the time in seconds. Errors count only in the increased time of performance.

TRAIL MAKING

Part A

SAMPLE

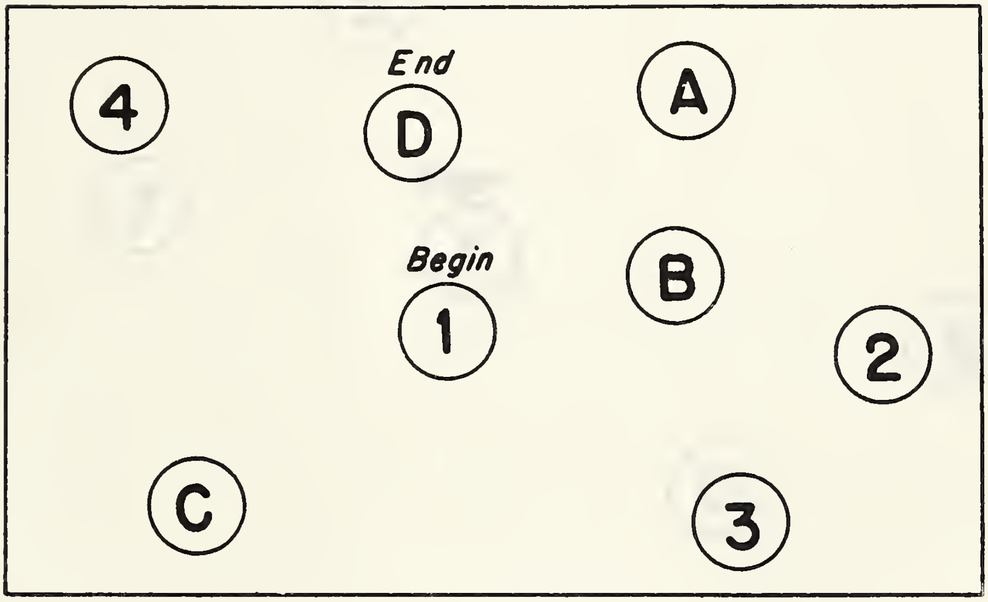


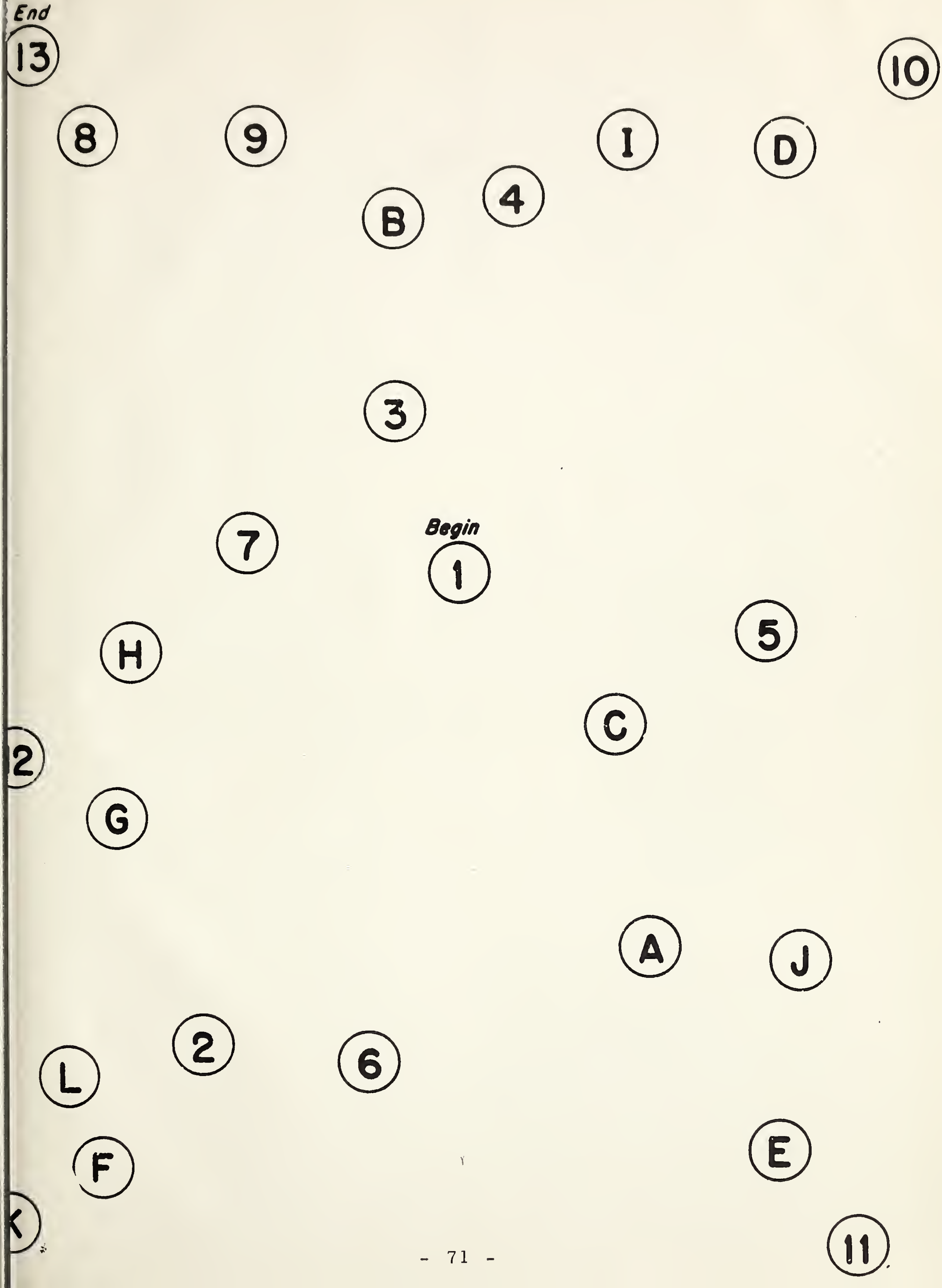

15
17
21
20
19
16
18
4
22
5
13
6
Begin
1
24
7
14
2
10
8
3
9
End
25
11
12
23

TRAIL MAKING

Part B

SAMPLE




End
13
10
8
9
I
D
4
B
3
7
Begin
1
5
H
C
2
G
A
J
2
6
L
F
E
K
11

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